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Editorial

Focus Point on Complex Photonics

Measurements, Theory and Simulations for Extreme Light-Matter Interactions

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The complexity and scope of advanced photonic applications has grown considerably during the past decades, pushed by unceasing efforts and breakthroughs coming from different fields. Building on the lively development of exotic structured materials and their modelling at the nanoscale, novel light-matter regimes and phenomena become increasingly accessible enabling exciting insights in cavity quantum electrodynamics, tailored spontaneous emission, optical telecommunications and high-efficiency energy harvesting and conversion.

Two main fields driving this photonic revolution are indeed represented by plasmonics and metamaterials, due to their complementary ability to overcome or circumvent many fundamental limits and give rise to unexplored effects such as non-reciprocal propagation, topological effects, optical magnetism and sub-diffraction imaging and light manipulation.

As a result, the way we think and design materials with emergent synthetic properties is undergoing a paradigm shift, increasing the need for new theoretical tools, numerical models and experimental platforms to orient oneself in this new landscape of possibilities.

In this scenario, one of the main theoretical challenges associated with the constant strive towards extreme confinement in metallic nanostructures, is that of modelling how the electronic response and density of states is influenced by the low effective dimensionality of these systems and the consequent quantum confinement effects. In this respect, it becomes necessary to develop models allowing to reliably predict the modified dispersion relations and shifted resonances of highly localized surface plasmon polaritons. A detailed treatment of this issue in the case of Au nanowires is reviewed in the tutorial paper by C.E.A. Cordaro, G. Piccitto and F. Priolo, for a wide array of geometrical configurations.

A second key challenge for the technological advances in the fields of metamaterials, plasmonics and nanophotonics is that of not just designing novel optical properties in next-generation materials, but rather to control them in a fully reversible way. An exciting perspective is that of exploiting the design flexibility of metamaterials to induce extreme light-matter interaction regimes. As an exemplary configuration, coupling the photonic modes of artificial cavity photon resonators with the magnetic cyclotron transition of a high mobility two-dimensional electron gas allows the direct observation of non-adiabatic cavity QED effects. The paper of J. Keller, C. Maissen, G. Scalari, M. Beck, J. Faist, S. Cibella and R. Leoni moves from this point taking a further step towards controlling the properties of the resulting ultra-strongly coupled state, implementing a switchable resonance supported by the onset of a superconductive state in a metasurface composed by split-ring resonators as terahertz cavities.

We are convinced that these two excellent papers above, forming a *Focus Point* on two particular aspects of complex photonics materials, will be interesting for experts, for newcomers and for generally interested readers alike. They also represent a timely snapshot of two very significant developments in the field, with many further interesting and possibly unexpected new insights to arrive in the coming years.

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